US009333809B2

(12) **United States Patent**
Mellara et al.

(10) **Patent No.:** **US 9,333,809 B2**
(45) **Date of Patent:** **May 10, 2016**

(54) **TREAD STRIP WITH GROOVES FEATURING NOISE-REDUCING MEANS**

(75) Inventors: **Beatrice Mellara**, Rome (IT); **Marco Ballatore**, Bertinoro (IT); **Carlo Fabrizi**, Rome (IT)

(73) Assignee: **BRIDGESTONE CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 798 days.

(21) Appl. No.: **13/641,630**

(22) PCT Filed: **Apr. 20, 2011**

(86) PCT No.: **PCT/IB2011/000864**

§ 371 (c)(1),
(2), (4) Date: **Jan. 25, 2013**

(87) PCT Pub. No.: **WO2011/132064**

PCT Pub. Date: **Oct. 27, 2011**

(65) **Prior Publication Data**

US 2013/0112326 A1 May 9, 2013

(30) **Foreign Application Priority Data**

Apr. 20, 2010 (IT) TO2010A0325

(51) **Int. Cl.**
B60C 11/13 (2006.01)
(52) **U.S. Cl.**
CPC *B60C 11/13* (2013.01); *B60C 2011/1338* (2013.04)
(58) **Field of Classification Search**
CPC B60C 19/002; B60C 2011/1338; B60C 2011/1361; B60C 11/1369; B60C 11/13

USPC 152/209.2, 209.3, 209.19, 209.21, 152/209.22
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2001/0032691 A1* 10/2001 Ohsawa 152/209.18
2008/0078487 A1* 4/2008 Ohara 152/209.19

FOREIGN PATENT DOCUMENTS

JP	H0699705 A	4/1994
JP	9-002020 A	1/1997
JP	H10905 A	1/1998
JP	2006-137231 A	6/2006
JP	2007001434 A	1/2007
JP	2008037139 A	2/2008
JP	2010042695 A	2/2010
WO	2009/053353 A1	4/2009

OTHER PUBLICATIONS

JP 6-99705, Apr. 1994, English language machine translation, Japan Platform for Patent Information [https://www4.j-platpat.inpit.go.jp/eng/tokujitsu/tkbs_en/TKBS_EN_GM101_Top.action].*
Communication dated Apr. 14, 2015 from the Japanese Patent Office in counterpart application No. 2013-505564.

* cited by examiner

Primary Examiner — Eric Hug
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

A tread strip made of at least one rubber-based material, and having at least one longitudinal groove bounded by a bottom wall and by two lateral walls on opposite sides of the bottom wall; wherein a number of pins seamlessly project from at least one of the walls of the longitudinal groove, and are made of the same rubber-based material than the tread strip.

26 Claims, 17 Drawing Sheets
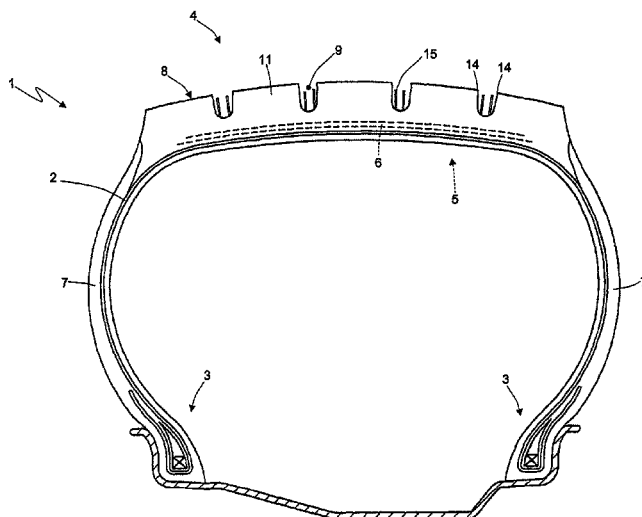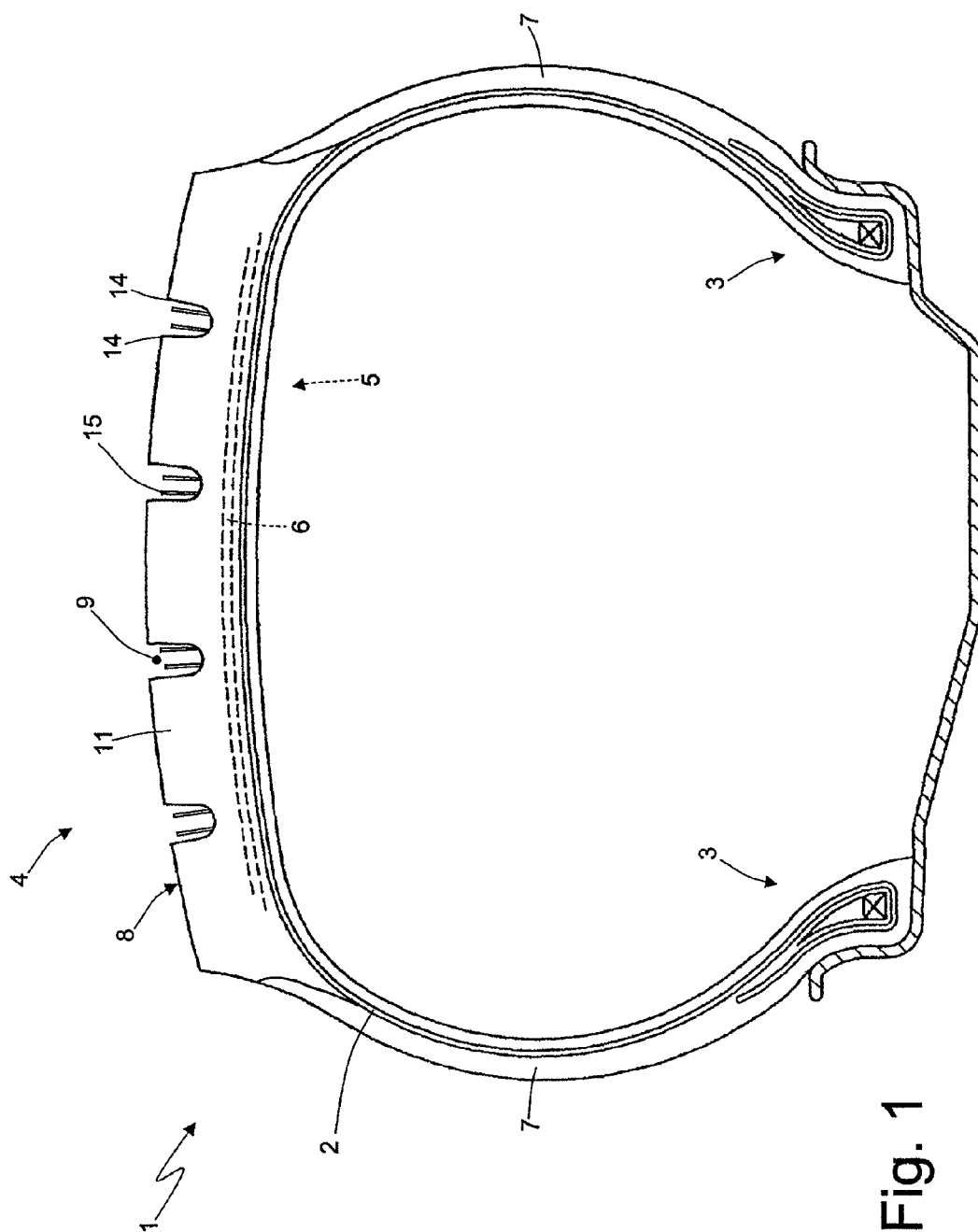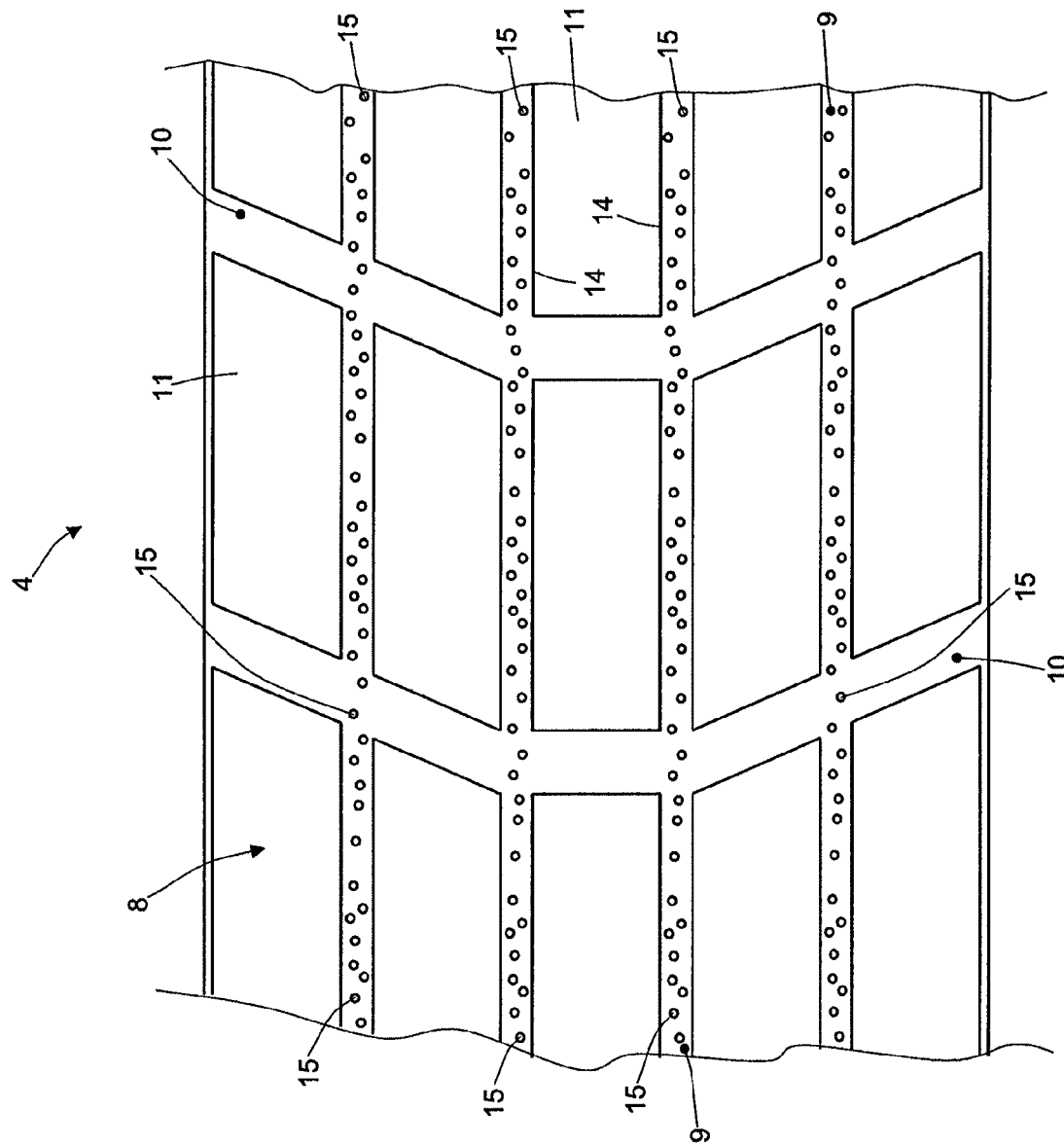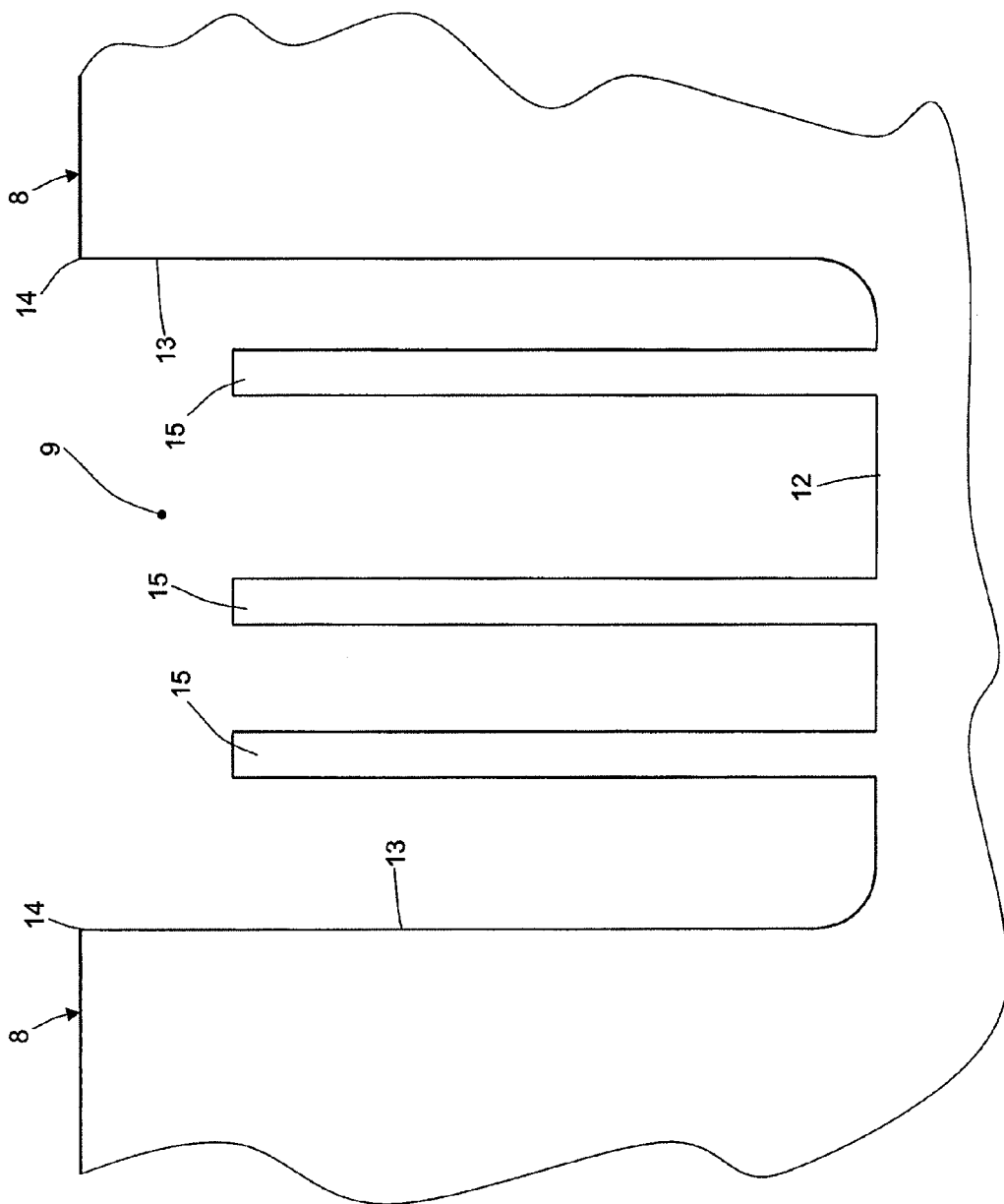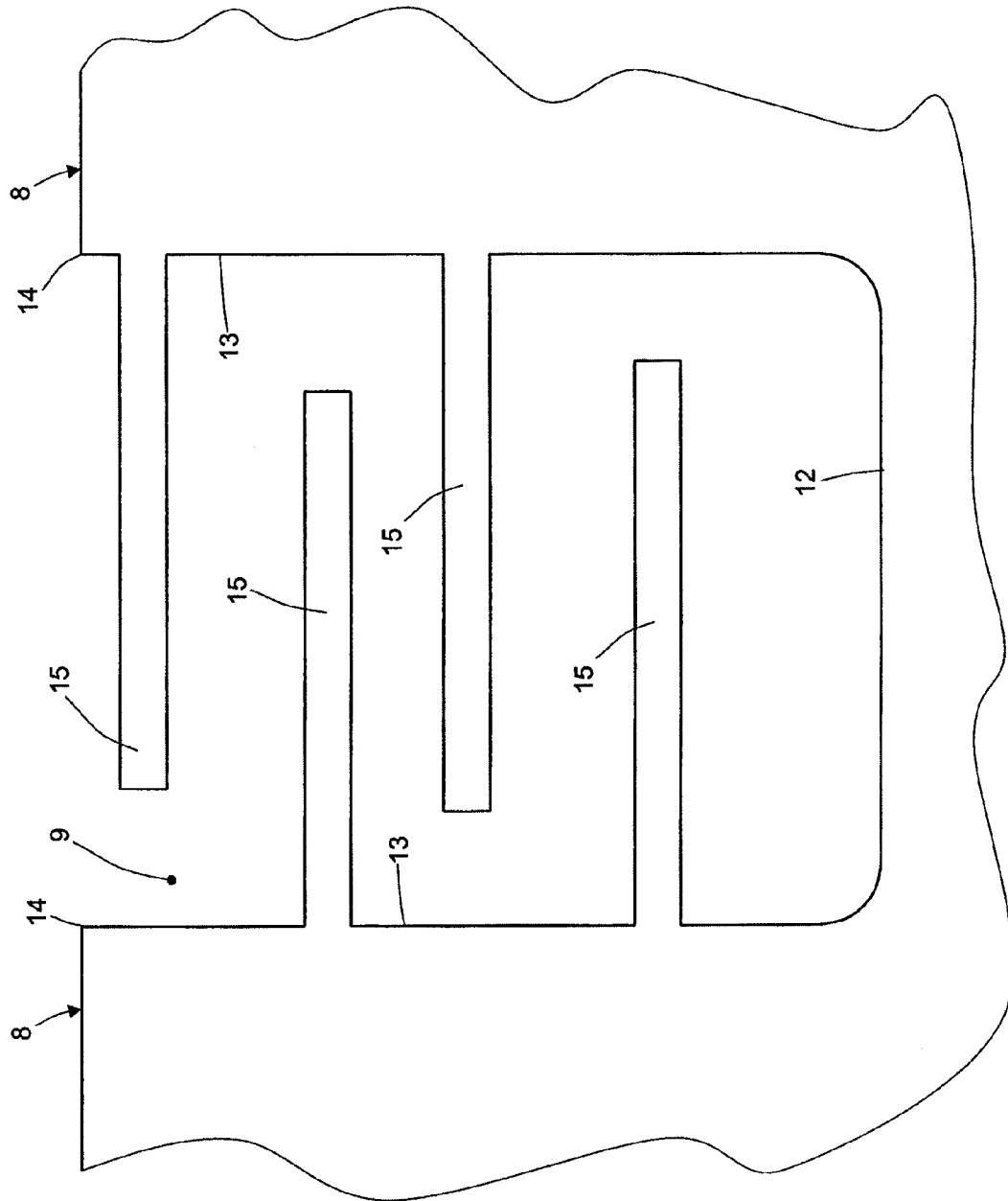
Fig. 1

Fig. 2

Fig. 3

Fig. 4
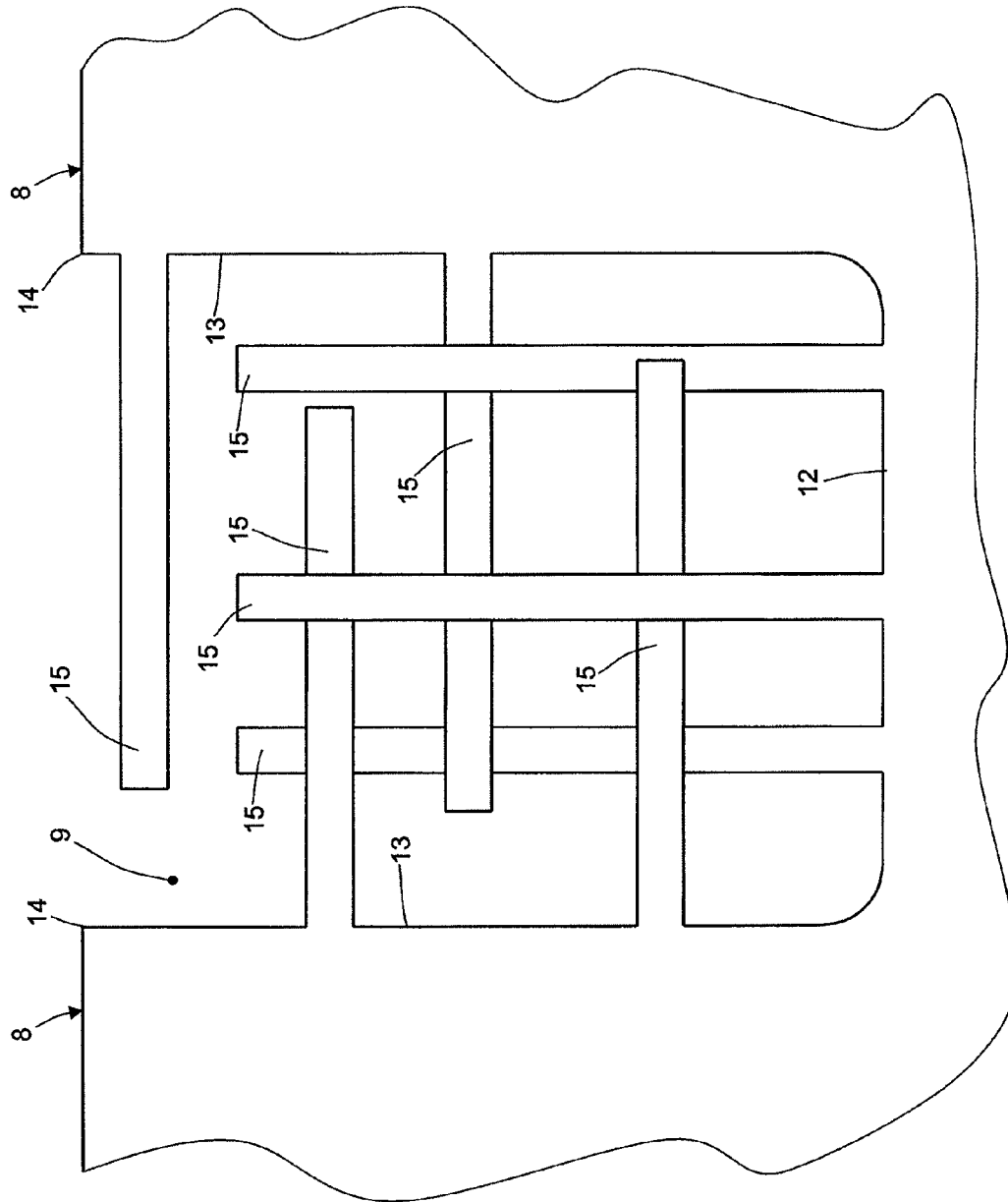
Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11
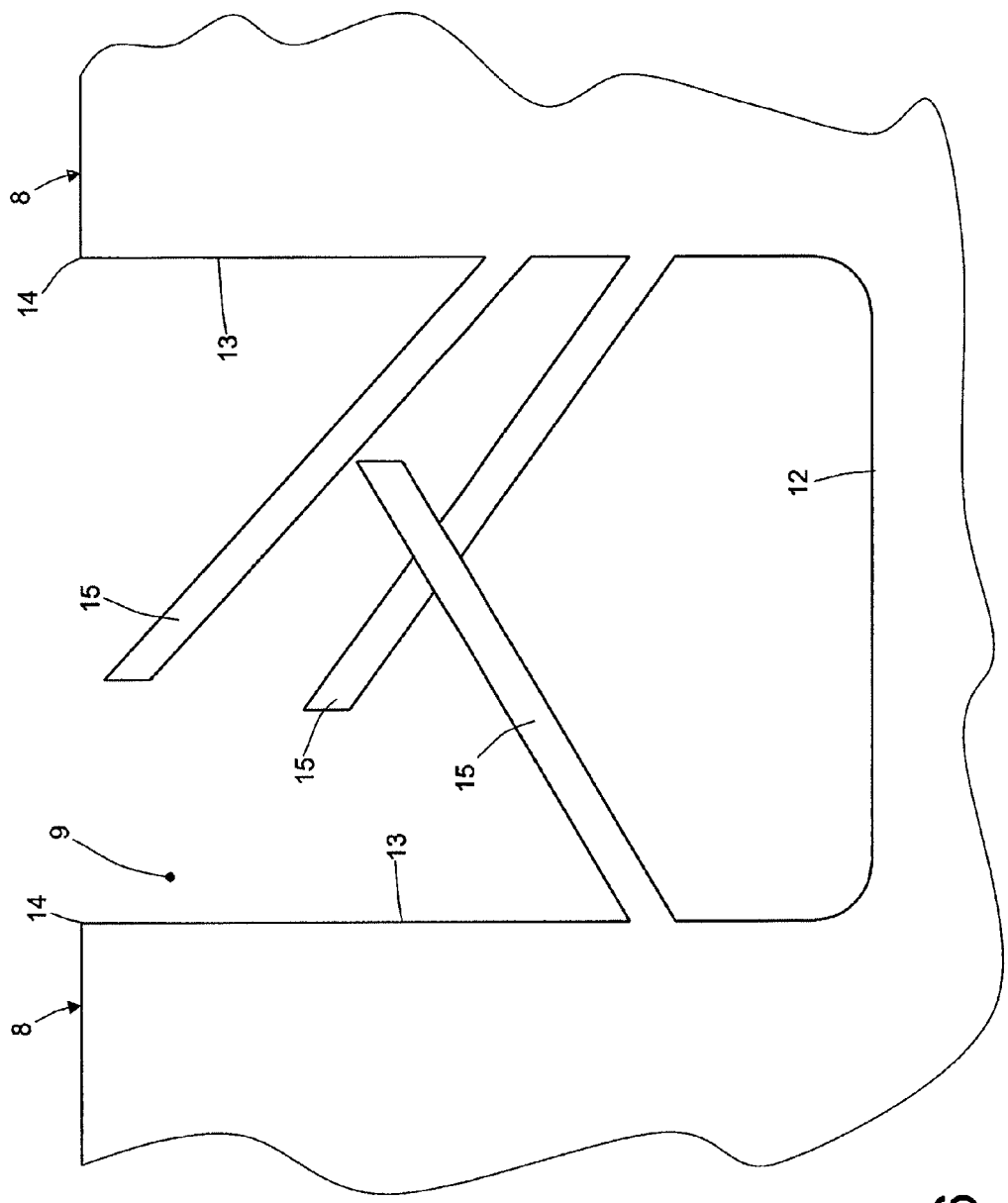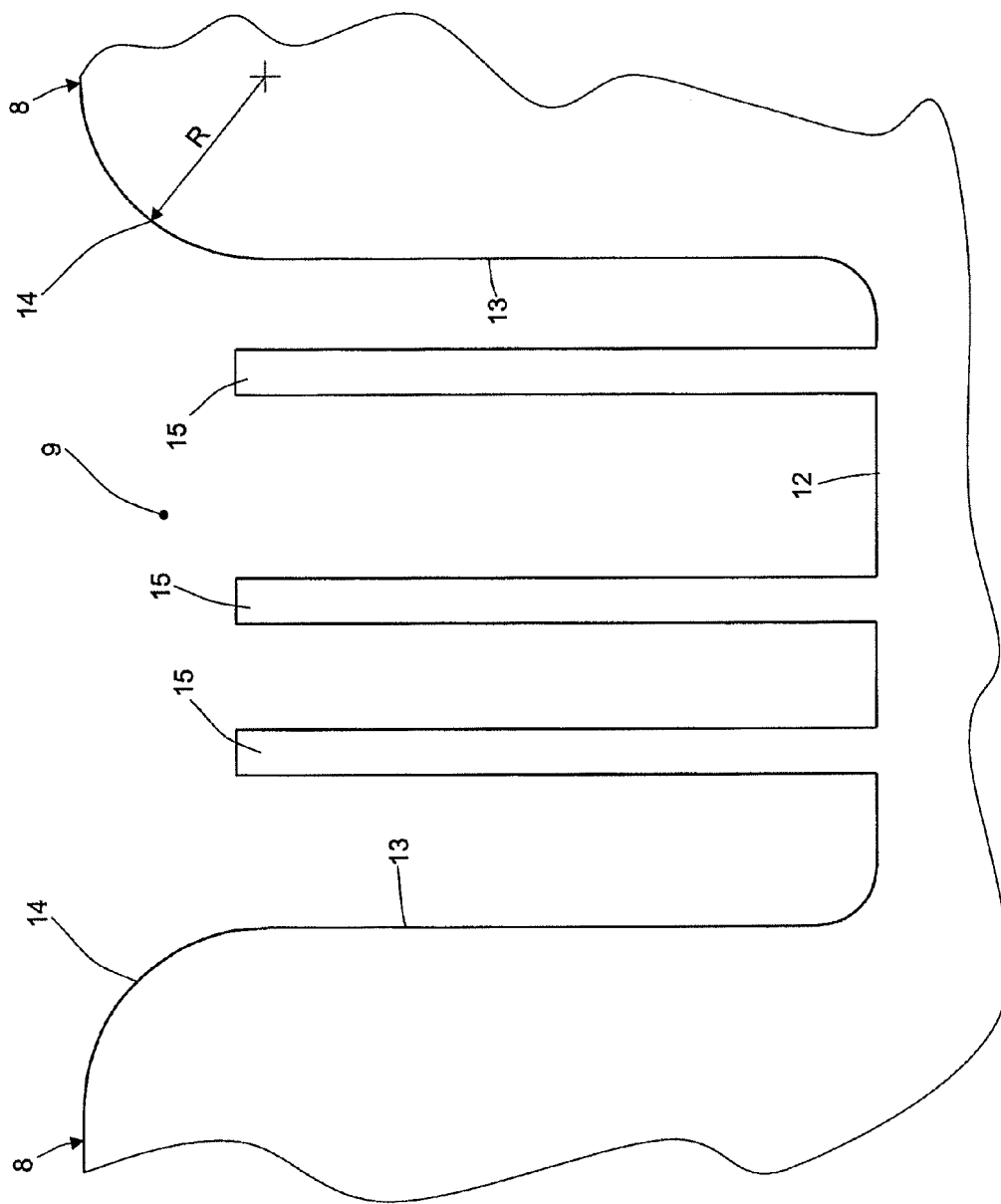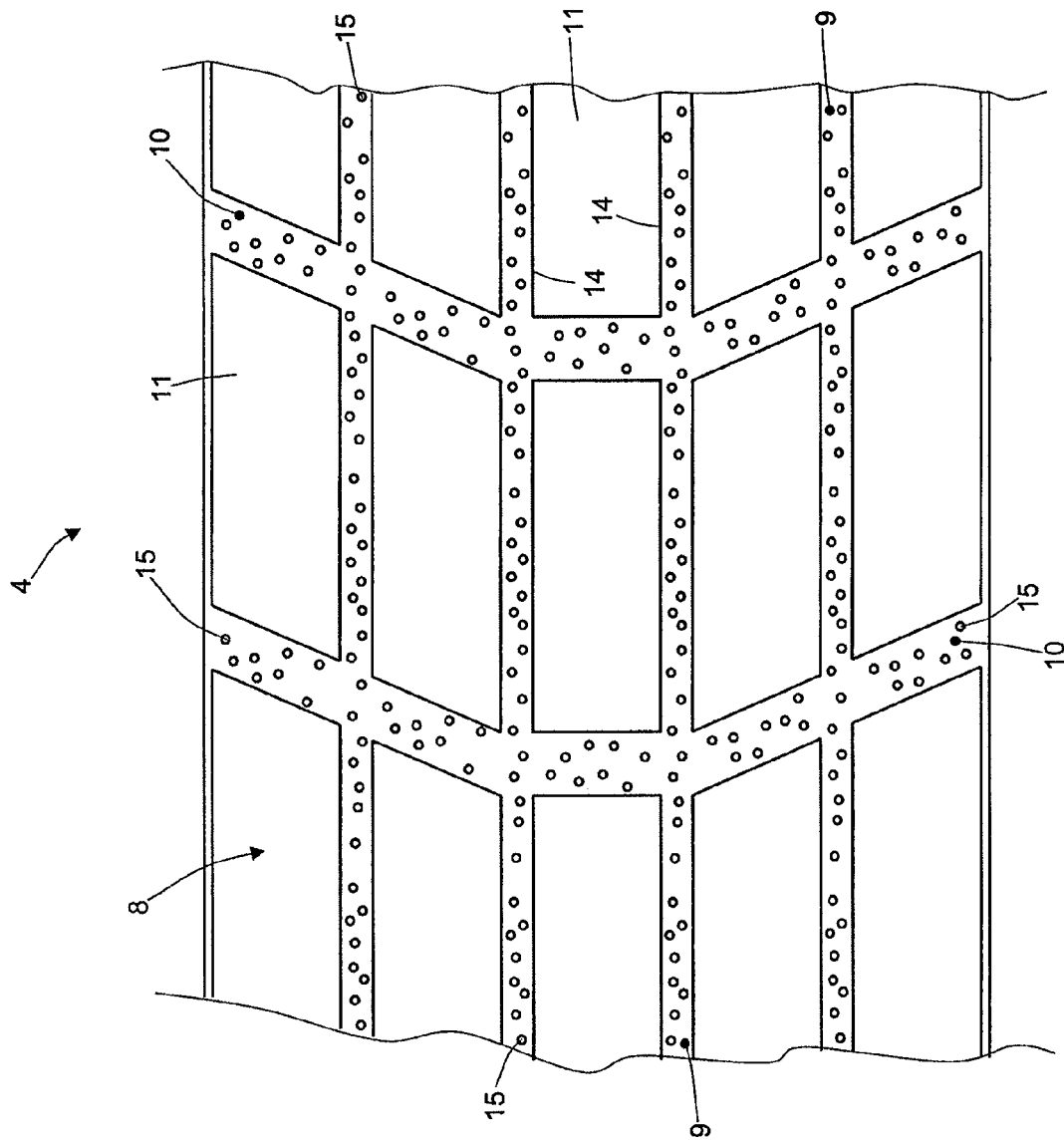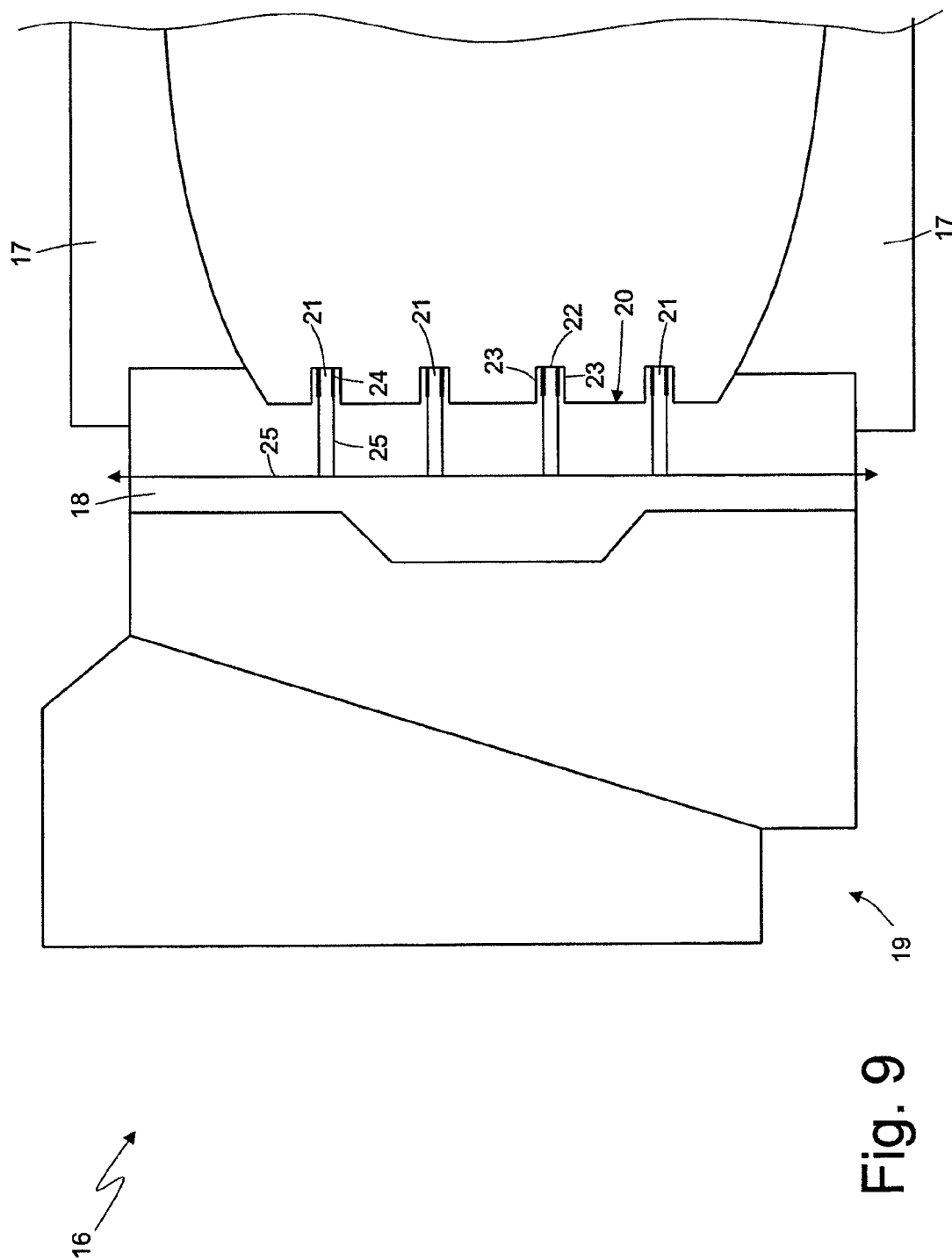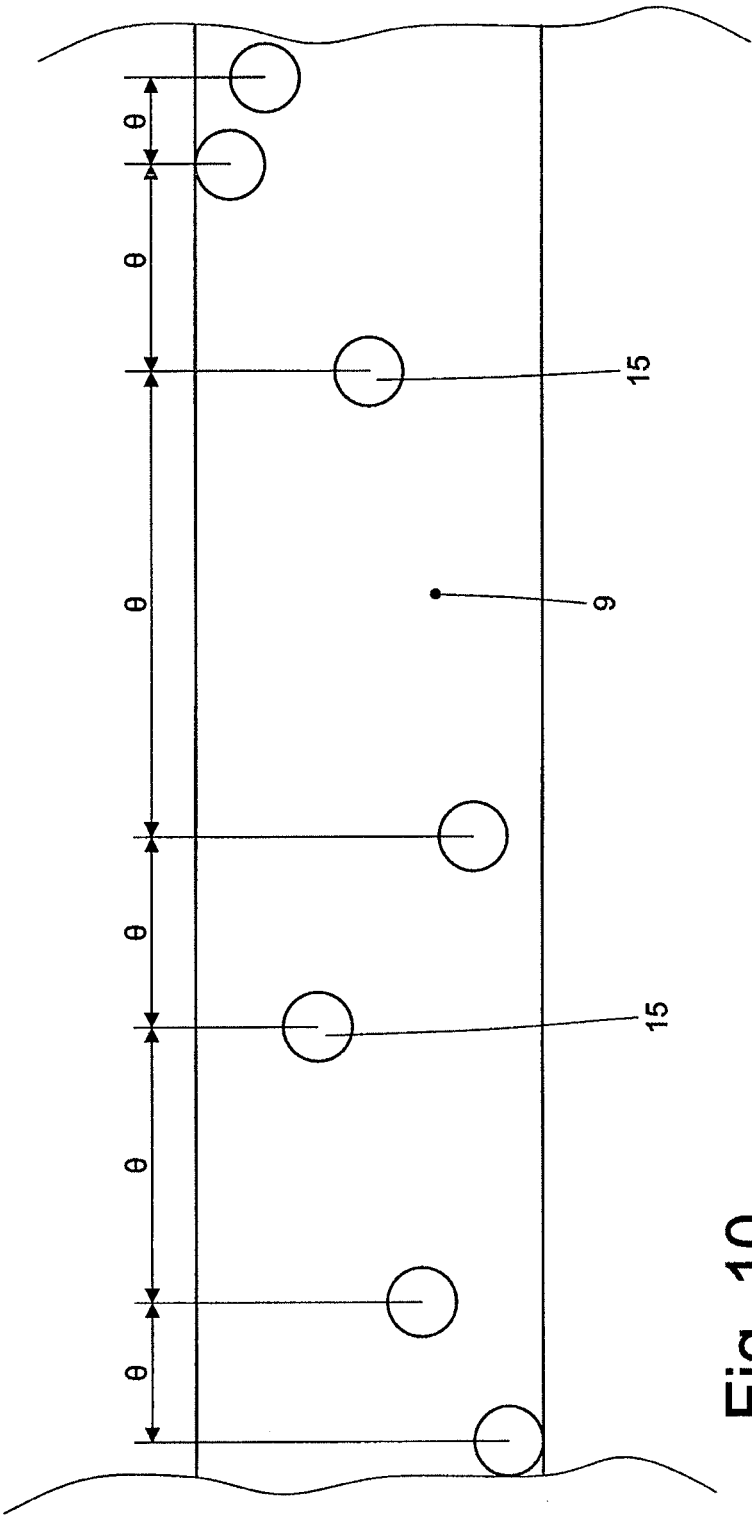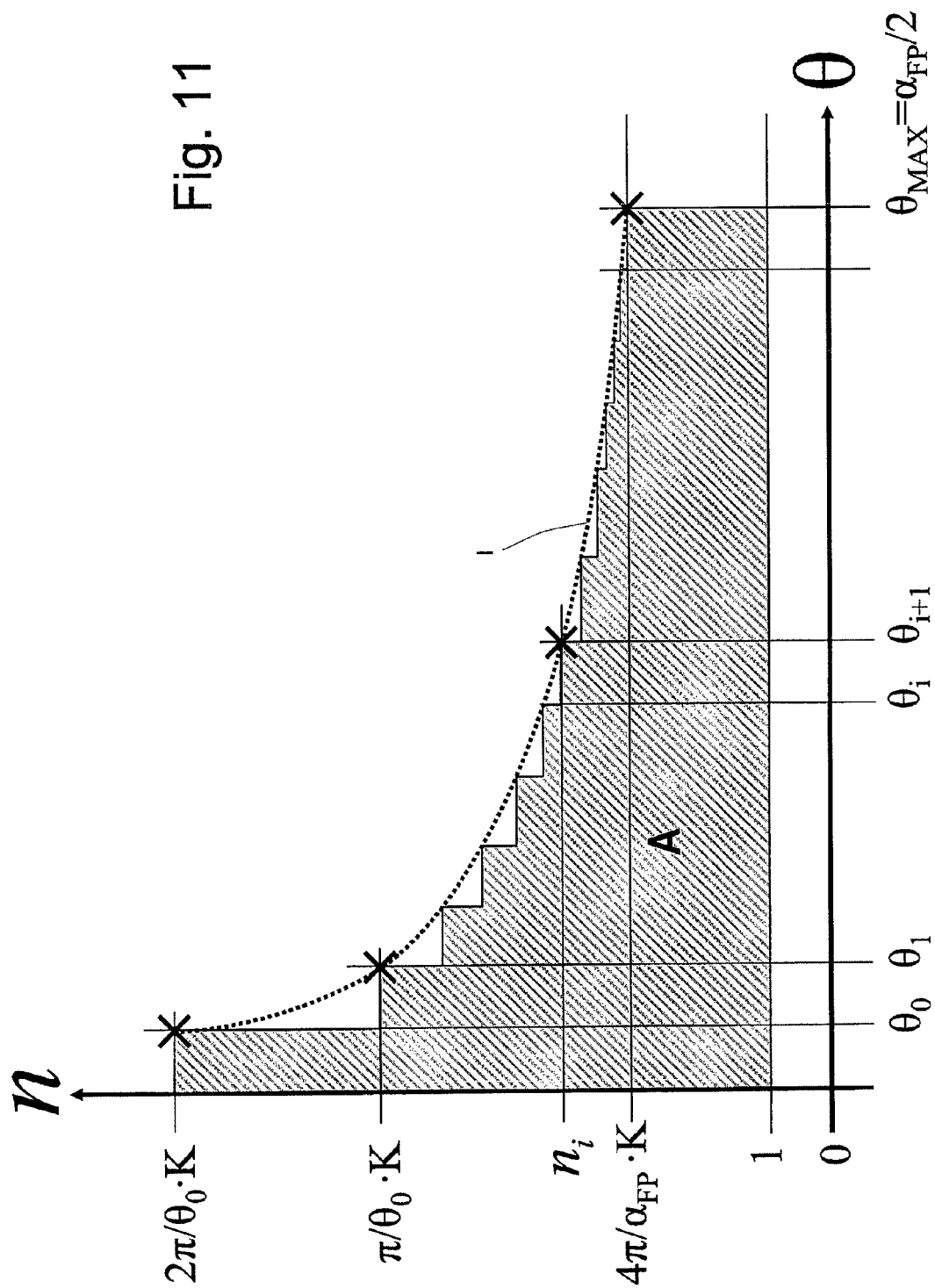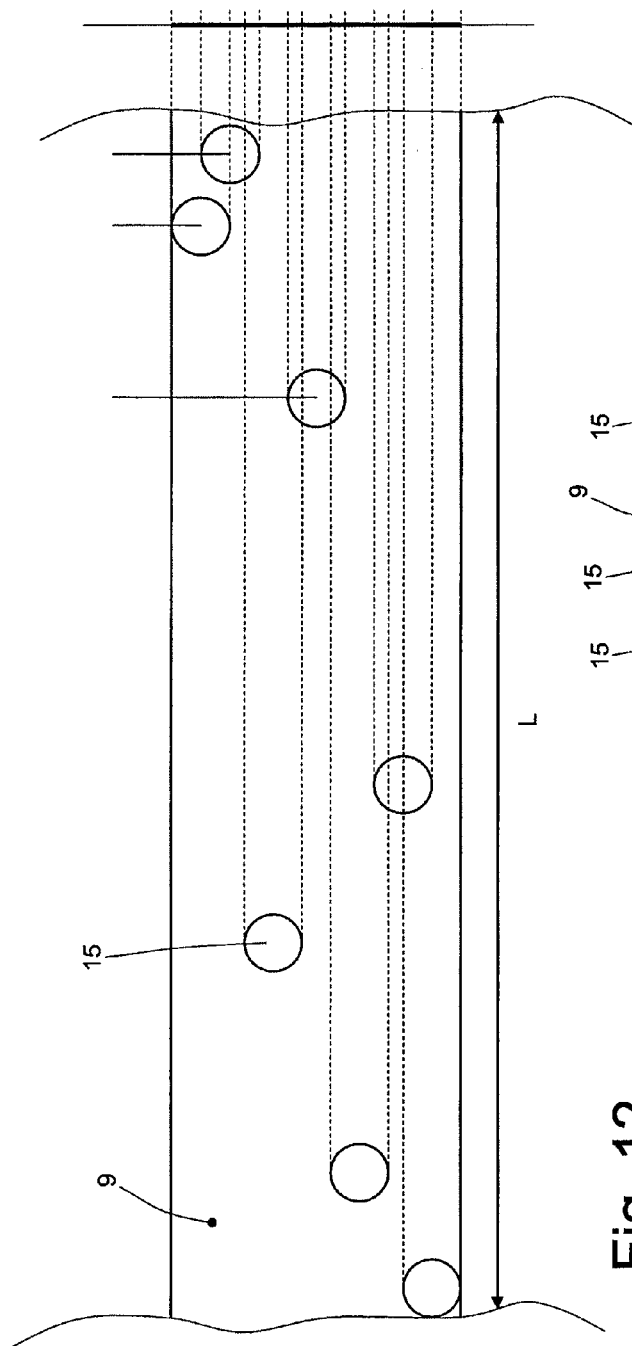
Fig. 12
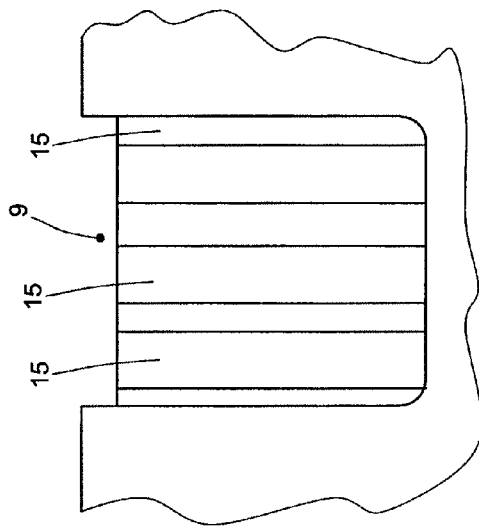
Fig. 13
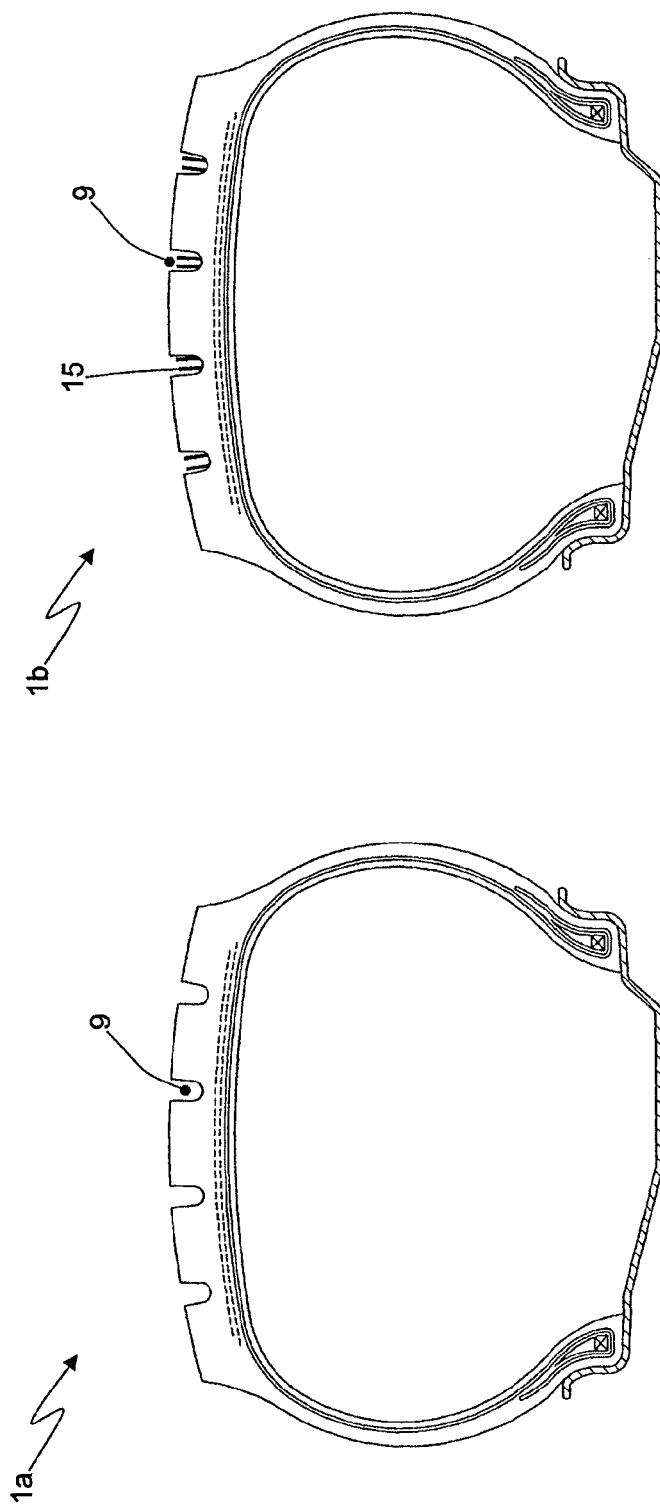
Fig. 14
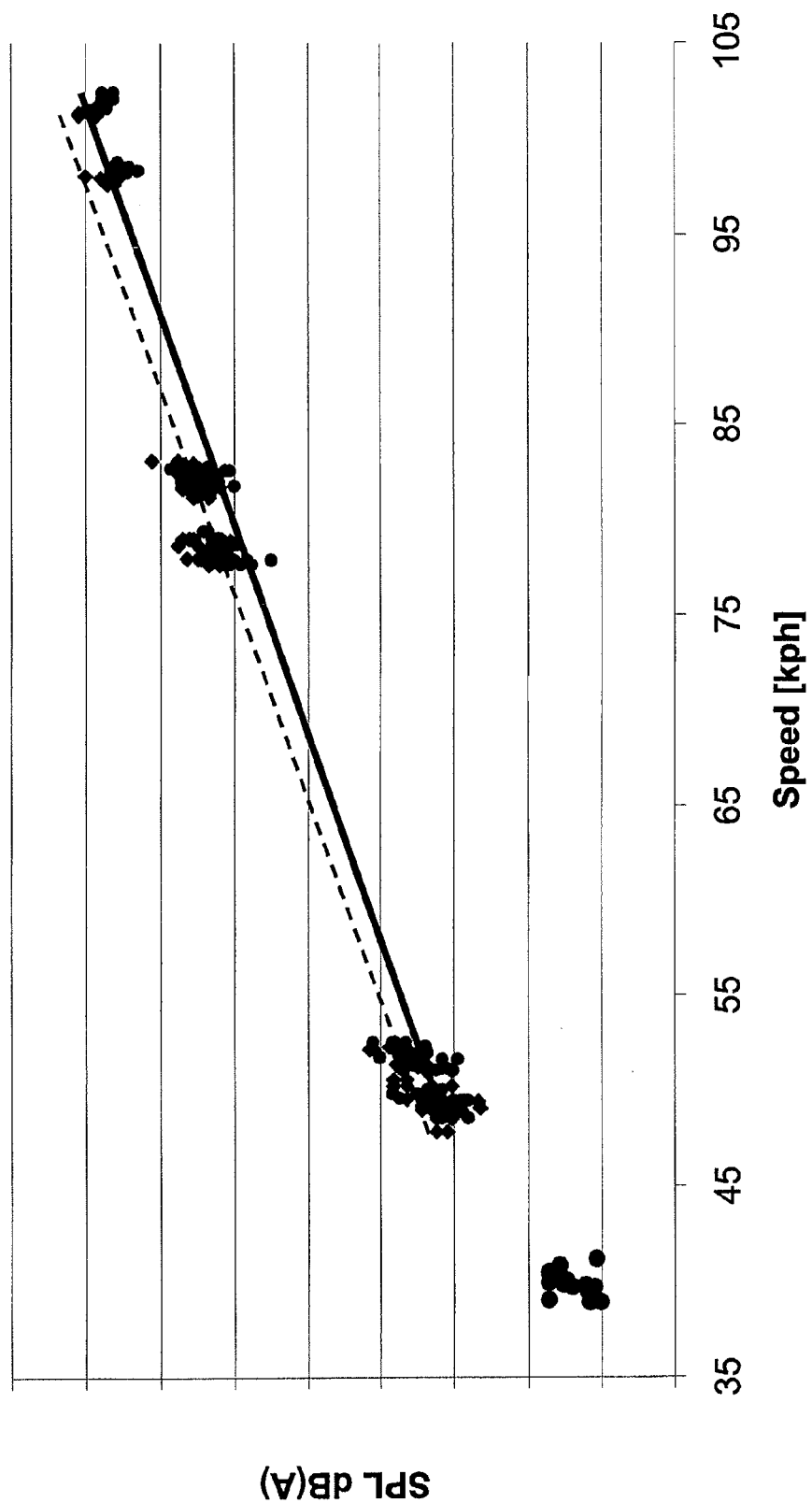
Fig. 15
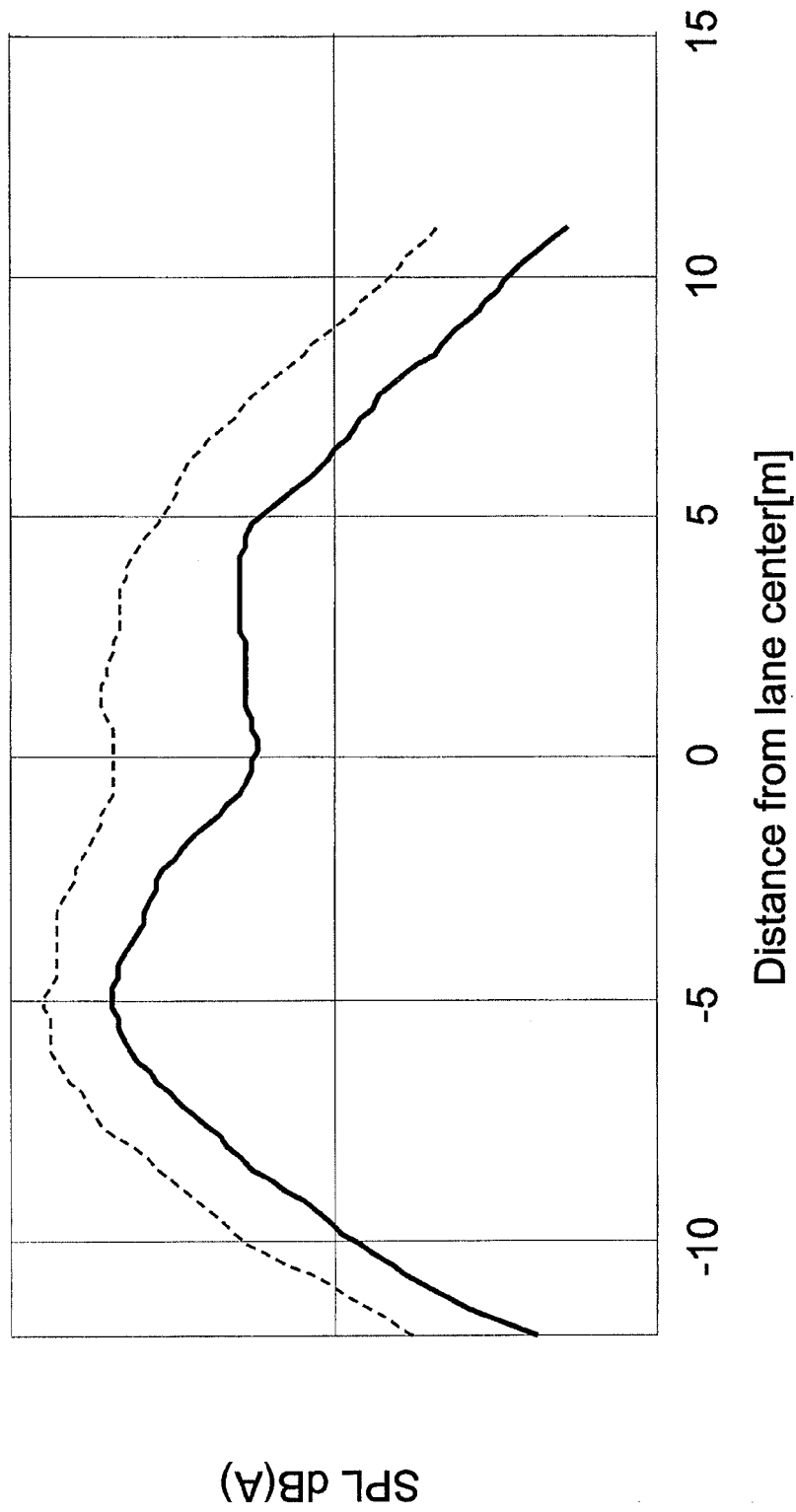
Fig. 16
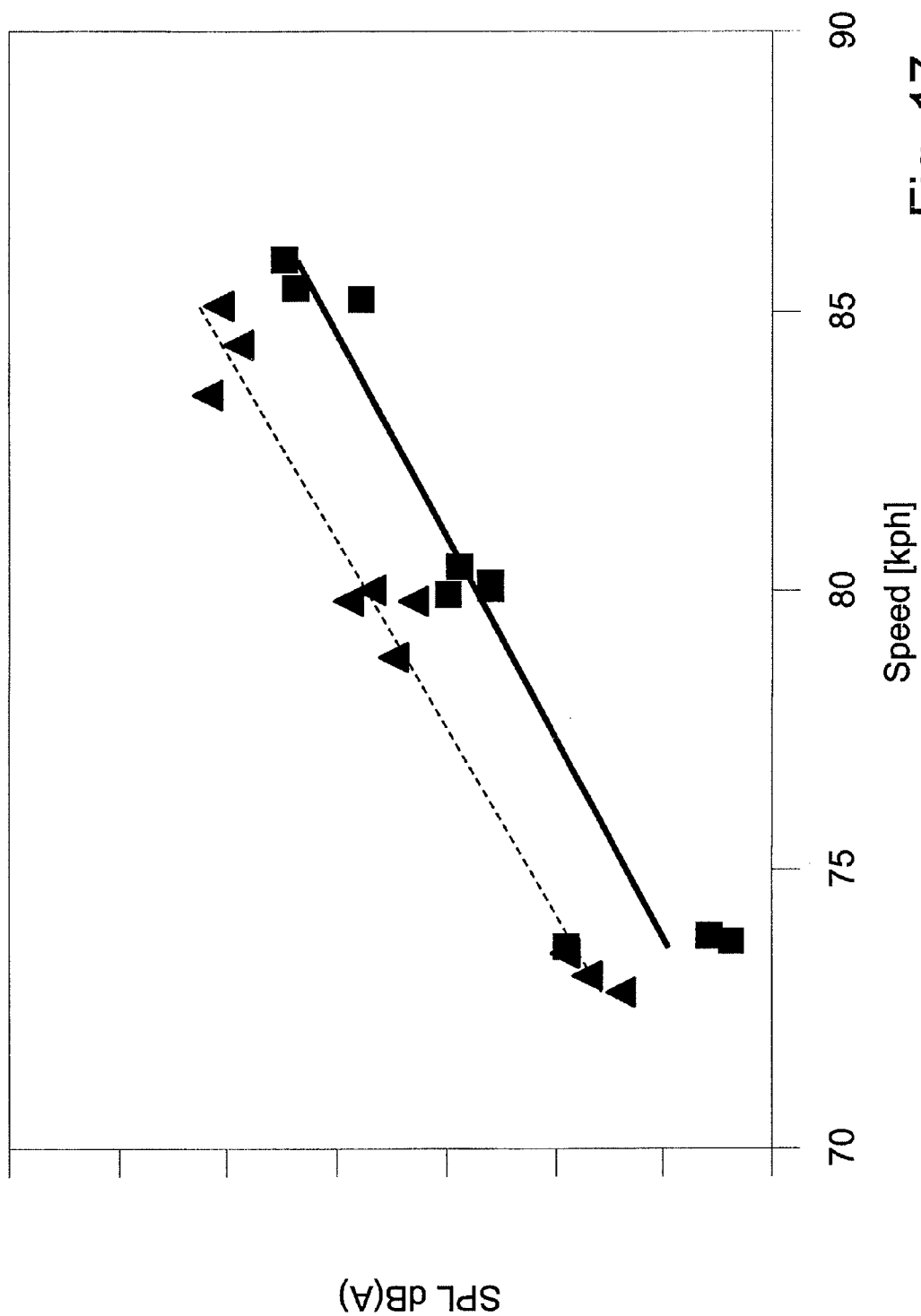
Fig. 17
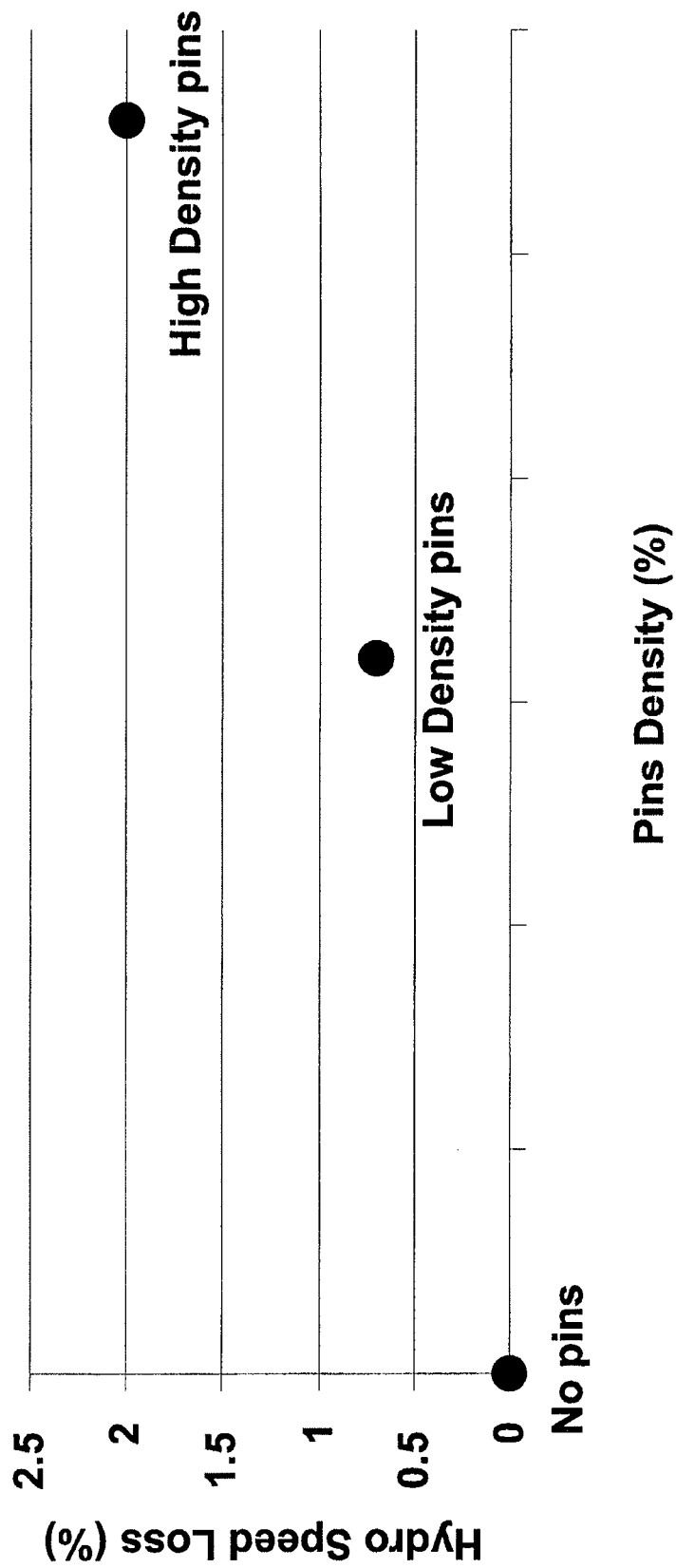
Fig. 18

TREAD STRIP WITH GROOVES FEATURING NOISE-REDUCING MEANS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Stage of International Application No. PCT/IB2011/000864 filed Apr. 20, 2011, claiming priority based on Italian Patent Application No. TO2010A000325 filed Apr. 20, 2010, the contents of all of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The present invention relates to a tread strip with grooves featuring noise-reducing means.

BACKGROUND ART

Future tyre certification standards are expected to call for a reduction in the maximum noise level produced as the tyre rolls along the road surface; which means steps must be taken forthwith to reduce such noise.

Patent Application WO2009053353A1 describes a low-noise tyre, in which the tread strip grooves contain fine (therefore highly flexible) threads of 20-80 micron in diameter, and made of material (nylon, PET, acrylic, cotton, linen, wool or rayon) other than the rubber from which the tread strip is made. The threads inside the grooves have a fairly high density (2-50 threads/mm^2) and serve to prevent the formation inside the grooves of stationary pressure waves resulting in noise emissions in the audible range (roughly between 1 and 4 kHz).

The threads described in Patent Application WO2009053353A1, however, are extremely complicated (therefore, expensive) to produce, by having to attach to the tread rubber a large number of fine threads of material (normally plastic) different from that of the tread. Moreover, attachment of the threads to the tread rubber must be mechanically strong enough to withstand the stress produced, as the tyre rolls along the road surface, by the centrifugal force generated by rotation and deformation of the tread at the point contacting the road surface. As the tyre rolls, the threads in the tread strip grooves also tend to get entangled in uneven road surfaces and so ripped out from the tread strip.

Patent Application JP9002020 describes a low-noise tyre, in which the longitudinal grooves in the tread strip contain noise-reducing pins projecting from the lateral walls of the grooves to a maximum length of 0.5 to 3.0 mm.

Patent Application JP2006137231 describes a tyre, in which the lateral longitudinal grooves in the tread strip contain pins projecting from the lateral walls of the grooves to a maximum length of 0.5 to 3.0 mm.

DESCRIPTION OF THE INVENTION

It is an object of the present invention to provide a tread strip with grooves featuring noise-reducing means, which strip is designed to eliminate the above drawbacks, and in particular is cheap and easy to produce.

According to the present invention, there is provided a tread strip with grooves featuring noise-reducing means, as claimed in the attached Claims.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of non-limiting embodiments of the present invention will be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 shows a schematic side section of part of a tyre featuring a tread strip in accordance with the present invention;

FIG. 2 shows a schematic, larger-scale plan view of a portion of the FIG. 1 tyre tread strip;

FIG. 3 shows a schematic, larger-scale cross section of a longitudinal groove of the FIG. 1 tyre tread strip;

FIGS. 4-7 show schematic, larger-scale cross sections of variations of the longitudinal groove in FIG. 3;

FIG. 8 shows a schematic, larger-scale plan view of a portion of the FIG. 1 tyre tread strip in accordance with a further variation;

FIG. 9 shows a schematic section of part of a curing mold by which to produce the FIG. 1 tyre;

FIG. 10 shows a schematic, larger-scale plan view of part of a longitudinal groove of the FIG. 1 tyre tread strip;

FIG. 11 shows a graph of an acceptable distribution of longitudinal distances (measured in angles) between consecutive pins;

FIG. 12 shows a schematic, larger-scale plan view of a footprint-length portion of a longitudinal groove of the FIG. 1 tyre tread strip;

FIG. 13 shows a schematic side view of the FIG. 12 longitudinal groove portion;

FIG. 14 shows a schematic of two identical test tyres, one without pins, and the other with pins in the longitudinal grooves;

FIGS. 15-18 show comparative test result graphs of the noise levels of the FIG. 14 tyres.

PREFERRED EMBODIMENTS OF THE INVENTION

Number 1 in FIG. 1 indicates as a whole a tyre comprising a toroidal body ply 2 having two annular beads 3 and supporting a tread strip 4 made of cured-rubber-based material. A tread belt 5, comprising two tread plies 6, is interposed between body ply 2 and tread strip 4; and each tread ply 6 comprises a rubber strip, in which side by side cords (not shown) are embedded a given distance apart and at a given angle to the equatorial plane of tyre 1. Body ply 2 also supports two sidewalls 7 between tread strip 4 and beads 3.

As shown more clearly in FIG. 2, tread strip 4 has a rolling surface 8, which bounds tread strip 4 externally (i.e. is located radially outwards), rests on the road surface in use, and in which is formed a raised pattern comprising a number of longitudinal or circumferential grooves 9 (i.e. extending crosswise to the rotation axis, and along the circumference, of tyre 1), and a number of transverse grooves 10 (i.e. parallel to the rotation axis of tyre 1 and perpendicular to longitudinal grooves 9). Longitudinal grooves 9 and transverse grooves 10 form five longitudinal rows of blocks 11, in which each block 11 projects radially from tread strip 4, is substantially parallelepiped-shaped with a rectangular or trapezoidal cross section, and is bounded laterally by grooves 9 and 10.

As shown in FIG. 3, each groove 9, 10 is bounded by a bottom wall 12; and by two lateral walls 13 located on opposite sides of bottom wall 12 and forming respective edges 14 with rolling surface 8.

Each longitudinal groove 9 has a number of pins 15, each of which extends upwards from and forms a seamless offshoot of bottom wall 12 of longitudinal groove 9, and is made seamlessly of the same rubber-based material as tread strip 4. In other words, as opposed to being a separate body inserted (i.e. incorporated) partly inside bottom wall 12, each pin 15 is an 'outgrowth' of bottom wall 12, which projects from and

forms a seamless whole with bottom wall **12**, so there is no connection or join between bottom wall **12** and each pin **15**.

Pins **15** serve to prevent the formation inside longitudinal grooves **9** of stationary pressure waves resulting in noise emissions in the audible range (roughly between 1 and 4 kHz). In other words, by preventing the formation of stationary pressure waves in longitudinal grooves **9**, pins **15** act, not as 'sound absorbers' (i.e. absorbing or shielding noise emissions), but as 'sound preventers' (i.e. preventing noise emissions by preventing orderly, i.e. audible, formation of the wave).

Tests show that pins **15** in longitudinal grooves **9** are capable of reducing total noise emission, caused by tyre **1** rolling on the road surface, by as much as 1 to 2 db.

In the FIG. **1-3** embodiment, pins **15** extend upwards from bottom wall **12** of each longitudinal groove **9**. In the FIG. **4** embodiment, pins **14** project from lateral walls **13** of each longitudinal groove **9**. And, in the FIG. **5** embodiment, pins **15** extend upwards from bottom wall **12**, and also project from lateral walls **13** of each longitudinal groove **9**.

In the FIG. **6** embodiment, pins **15** extend upwards from lateral walls **13** of each longitudinal groove **9**, form an angle of other than 90° with lateral walls **13** (i.e. at the point of attachment to lateral walls **13**) of each longitudinal groove **9**, and originate from points located between bottom wall **12** and half the total depth of longitudinal groove **9**, so that, even when tread strip **4** wears down (i.e. reducing the depth of grooves **9** and **10** and the height of lateral walls **13**), pins **15** still extend upwards from the unworn part of lateral walls **13**.

In the FIG. **3-5** embodiments, pins **15** are perpendicular to walls **12** and **13** of longitudinal groove **9**. In the FIG. **6** embodiment, pins **15** form an angle of other than 90° with lateral walls **13** (i.e. at the point of attachment to lateral walls **13**) of longitudinal groove **9**.

In the embodiments shown in the drawings, each pin **15** has a constant cross section along its whole length. In a different embodiment not shown, each pin **15** may vary in cross section along its length, and in particular may be wider at the base attached to wall **12** or **13** (i.e. may taper away from wall **12** or **13** from which it originates).

In the embodiments shown in the drawings, each pin **15** is straight. In a different embodiment not shown, each pin **15** may be other than straight (e.g. curved, coiled, twisted, braided, . . .).

It is important to note that each pin **15** is fully contained inside longitudinal groove **9**, i.e. does not project from longitudinal groove **9** or rolling surface **8**. More specifically, in a preferred embodiment, each pin **15** extending upwards from bottom wall **12** of longitudinal groove **9** is of a length equal to 60-90% of the depth of longitudinal groove **9**.

Given the difficulty in producing pins **15** of different lengths, pins **15** are preferably all the same length.

The top portion of pin **15** (at least as long as tread strip **4** is not too badly worn) is thus prevented from being 'pinched' between rolling surface **8** and the road surface, which could result in pulling stress on and eventual breakage of pin **15**.

In the preferred embodiment shown in the drawings, each pin **15** is roughly cylindrical, possibly tapering towards the tip, and has a circular cross section of 0.3 to 1.2 mm and preferably of 0.5 mm in diameter. Alternatively, each pin **15** may have a rectangular cross section of 0.3 to 1.2 mm in width (short side of the rectangle), and 1 to 4 mm in length (long side of the rectangle). Rectangular cross section pins **15** may be oriented longitudinally (i.e. with the long side parallel to longitudinal grooves **9**, crosswise (i.e. with the long side perpendicular to longitudinal grooves **9**), or at an angle (i.e. with the long side, excluding the ends, at an angle of 0-90° to

longitudinal grooves **9**. A further variation may comprise both circular and rectangular cross section pins **15**; in which case, pins **15** of different cross sections may either be mixed, or divided into areas (i.e. areas of circular cross sections pins **15** alternating with areas of rectangular cross section pins **15**).

It is important that pins **15** be distributed randomly along each longitudinal groove **9** (i.e. that the longitudinal distances between adjacent pins **15** be irregular), so that pins **15** as a whole along each longitudinal groove **9** do not form a regular structure, thus preventing undesired resonance phenomena and, hence, natural resonance frequencies at least in the audible range (i.e. between 20 Hz and 20 kHz).

In one possible embodiment shown in FIG. **10**, pins **15** are distributed randomly by a random distribution of the longitudinal distances e between longitudinally consecutive pins **15**, i.e. by a relatively large number of different longitudinal distances θ with no multiple/submultiple relationship. For example, assuming a longitudinal groove **9** contains a thousand (1000) pins **15**, consecutive pins **15** are separated by a thousand (1000) longitudinal distances θ of a mean value (in degrees) of 0.36° (i.e. 360°/1000). If longitudinal distances θ are all equal (i.e. 0.36°), or if half of longitudinal distances θ are 0.18° (i.e. 0.36°/2), and the other half are 0.72° (i.e. 0.36°·2), this would result in a regular distribution that could easily give rise to undesired resonance phenomena. Conversely, if consecutive pins **15** are separated by numerous different unrelated longitudinal distances θ (i.e. with no multiple/submultiple relationship), this results in a random distribution that is unlikely to give rise to undesired resonance phenomena. For example, longitudinal distances θ may comprise all the distances between 0.03° and 0.80° in increments of 0.01° (i.e. 0.03°, 0.04°, 0.05° . . . 0.79°, 0.80°), with no particular longitudinal distance θ (or small number of longitudinal distances θ) occurring much more frequently than others.

With reference to the FIG. **11** graph, a mathematical rule can even be defined by which to determine (sufficiently) random distribution of longitudinal distances θ between consecutive pins **15**. Longitudinal distances θ between consecutive pins **15** are assumed (sufficiently) randomly distributed when they have at least two occurrence frequencies n in set A (diagonally hatched portion in FIG. **11**). Set A is defined by all the points, in the longitudinal distance θ/occurrence frequency n plane, between unit occurrence frequency n (i.e. n=1) and a hyperbola I, and is defined as follows:

$$\theta_0 = 2 \cdot D_{PIN}/D_{TYRE}$$

$$\theta_i = i \cdot \theta_0$$

$$n_i = \text{occurrence between } \theta_i \text{ and } \theta_{i+1}$$

$$A = \{n_i : n_i \epsilon [1, 2\pi/(\Theta_{i+1} \cdot K]; i=1, 2, \ldots, \alpha_{FP}/(2 \cdot \theta_0)\}$$

D_{PIN} diameter of pin **15**
D_{TYRE} diameter of tyre **1**
α_{FP} footprint angle
K safety coefficient greater than (1) and preferably at least two (2)

In a preferred embodiment shown in FIG. **13**, in each footprint of tread strip **4** (i.e. in each footprint-long portion of tread strip **4**), pins **15** in each longitudinal groove **9** are distributed so that, viewed longitudinally, pins **15** as a whole cover at least 80% (and preferably 100%) of the cross section of longitudinal groove **9**. In other words, viewed longitudinally, pins **15** as a whole in each footprint-long portion of a longitudinal groove **9** cover at least 80% (and preferably 100%) of the cross section of longitudinal groove **9**. That is,

'observing' a footprint-long portion of a longitudinal groove **9** from one end (as shown in FIG. **13**), at least 80% (and preferably 100%) of the inside of longitudinal groove **9** is covered with pins **15**.

In a preferred embodiment, pins **15** cover 0.45% to 25% of the total surface area of wall **12** or each wall **13** of longitudinal groove **9** (i.e. have a density ranging between 0.5 and 15 pins/cm^2). Whichever the case, pins **15** preferably occupy a volume no greater than 10% of the total volume of longitudinal groove **9**. The above values ensure pins **15** are easy to produce, are highly effective in attenuating noise emissions, and, at the same time, have no appreciable effect on wet-pavement draining performance of longitudinal grooves **9**.

As will be clear from the above description, each pin **15** has a relatively large diameter (roughly a few tenths of a millimeter) with respect to its length (of a few millimeters), and is made of the same rubber-based material as tread strip **4**. The rubber-based material being relatively hard and rigid (to ensure an acceptable working life of tread strip **4**), each pin **15** is deformable elastically, and has an undeformed shape which it springs back to and maintains when external mechanical stress is removed.

In the FIG. **7** embodiment, each edge **14** is rounded smoothly, in particular with a circular (i.e. quarter-circle-shaped) cross section. Rounding the top edges **14** of longitudinal grooves **9** (and blocks **11**) attenuates noise emissions as tyre **1** rolls along the road surface, but combining this with pins **15** has a surprisingly synergic effect, resulting in total noise emission attenuation far superior to that produced individually by pins **15** and rounded edges **14**. Tests show that pins **15** provide for attenuating noise emissions by 0.3-0.6 dB(A), and rounded edges **14** for attenuating noise emissions by 0.2-0.3 dB(A), whereas combining the two provides for attenuating noise emissions by 0.7-1.0 dB(A), i.e. by a far greater amount that the mere sum of the attenuations produced individually by pins **15** and rounded edges **14**.

Pins **15** attenuate propagation of longitudinal 800-1300 Hz sound waves along longitudinal grooves **9**, while rounding edges **14** attenuates over 1300 Hz sound waves, which, not propagating longitudinally, repeatedly strike the walls of longitudinal grooves **9**, and are attenuated if reflected from the walls into the funnel formed by the rounded edges. The synergic effect produced by combining pins **15** and rounded edges **14** is due to the longitudinal waves diverted laterally by pins **15** being attenuated by rounded edges **14**.

To maximize positive interaction between rounded edges **14** and pins **15**, the radius R of each edge **14** must range between 40 and 85% of the length of pins **15**, and therefore normally ranges between 3 and 5 mm.

In the FIG. **2** embodiment, pins **15** are only provided in longitudinal grooves **9**. In a different embodiment shown in FIG. **8**, pins **15** are also provided in transverse grooves **10**, but are much more effective in longitudinal grooves **9**. The lesser effectiveness of pins **15** in transverse grooves **10** is due to transverse grooves **10** extending crosswise to the rolling direction of tyre **1**, being much shorter than longitudinal grooves **9**, and so housing negligible stationary pressure waves.

In a conventional embodiment, tread strip **4** is made of one rubber-based material, which therefore also forms pins **15**. In an alternative embodiment, tread strip **4** is made of a first rubber-based material, which forms most of tread strip **4**, and a second rubber-based material, different from the first, which is located at grooves **9** and **10** and forms at least bottom walls **12** of grooves **9** and **10**, and pins **15** extending upwards from bottom walls **12**. The second rubber-based material is typically softer than the first, to make pins **15** more flexible and

more elastically deformable, and to improve noise emission attenuation performance as tyre **1** rolls along the road surface.

FIGS. **15-18** show comparative test result graphs of the noise levels of tyre **1a** on the left in FIG. **14**, featuring a tread strip **4** with no pins, and tyre **1b** on the right in FIG. **14**, featuring a tread strip **4** with pins **15** in longitudinal grooves **9**. Apart from the presence or absence of pins **15** in longitudinal grooves **9**, tyres **1a** and **1b** are perfectly identical, so any difference between the two can be attributed to the pins in tyre **1b**.

In FIG. **15**, the continuous line shows the noise level of tyre **1b** with pins **15**, and the dash line the noise level of tyre **1a** with no pins **15**, alongside variations in travelling speed. As can be seen, pins **15** provide for reducing noise by roughly 0.5-0.8 dB(A) at 80 km/h speed. It is important to note that the noise reduction by pins **15** decreases with travelling speed, and falls off altogether (i.e. pins **15** cease to have any appreciable effect) below 40 km/h speed.

In FIG. **16**, the continuous line shows the noise level of tyre **1b** with pins **15**, and the dash line the noise level of tyre **1a** with no pins **15**, at constant 80 km/h travelling speed. As can be seen, pins **15** provide for reducing noise by roughly 0.6 dB(A) at 80 km/h speed.

In FIG. **17**, the continuous line shows the noise level of tyre **1b** with pins **15**, and the dash line the noise level of tyre **1a** with no pins **15**, alongside variations in travelling speed. As can be seen, pins **15** provide for reducing noise by roughly 0.5-0.8 dB(A) at 80 km/h speed.

Tests show that the noise reduction by pins **15** increases with the density of pins **15**: at 80 km/h travelling speed, fewer pins **15** (low pin **15** density) reduce noise by roughly 0.4 dB(A), whereas a larger number of pins **15** (high pin **15** density) reduce noise by roughly 0.6 dB(A). The FIG. **18** graph shows the effect of pins **15** on wet-pavement performance of tyre **1**: using the wet-pavement cornering speed of tyre **1a** with no pins **15** as a reference, wet-pavement cornering speed is reduced by less than 1% by tyre **1b** with a low pin **15** density, and by roughly 2% by tyre **1b** with a high pin **15** density. It is important to note that pins **15** provide for a 0.4-0.8 dB(A) (i.e. 4-8%) reduction in noise at 80 km/h speed, alongside a 1-2% reduction in wet-pavement performance, i.e. the advantage in terms of noise reduction far outweighs the reduction in wet-pavement performance.

Number **16** in FIG. **9** indicates as a whole a curing mold for producing the tyre strip **4** described.

Curing mold **16** is in the form of a hollow cylinder, and comprises two opposite, parallel half-molds **17** forming the top and bottom walls of curing mold **16** and having respective inner retaining surfaces contacting a tyre **1** inside the mold. Curing mold **16** also comprises a number of (usually 8 or 9) lateral sectors **18** (only one shown in FIG. **9**), which are brought together to form the cylindrical lateral wall of the mold, are movable radially to and from half-molds **17**, and are pushed radially towards half-molds **17** by a system **19** of inclined surfaces operated by a press (not shown). This solution is preferred in that it enables lateral sectors **18** to grip half-molds **17** at the 25-30 bar pressure necessary to withstand the normally at least 20 bar pressure generated inside mold **16** during the curing process.

The inner surface **20** of lateral sectors **18** of curing mold **16** negatively reproduces the shape of tread strip **4**, and comprises, for each groove **9**, **10**, a respective projecting member **21**, which negatively reproduces the shape of groove **9**, **10**, and is bounded by an end wall **22**, and two lateral walls **23** on opposite sides of end wall **22**. Projecting members **21** of curing mold **16** forming longitudinal grooves **9** have holes **24**,

each of which originates from end wall **22** of projecting member **21** and negatively reproduces the shape of a pin **15**.

When the rubber-based material is inserted inside curing mold **16** (after first being looped about body ply **2**), the pressure inside mold **16** during the pressure curing process pushes part of the rubber-based material inside holes **24** to form pins **15**. In other words, during the pressure curing process, each hole **24** is filled with rubber-based material to form a pin **15** projecting from bottom wall **12** of longitudinal groove **9**.

Each hole **24** may be closed, i.e. completely isolated from the outside; in which case, it cannot be filled completely with rubber-based material, on account of the small amount of air inevitably trapped in the end of hole **24**. Alternatively, each hole **24** may communicate with the outside along a bleed duct **25** originating from end wall **22** of hole **24**; in which case, hole **24** can be filled completely with rubber-based-material, by gradually expelling air from hole **24** along bleed duct **25**.

In the above embodiment, tread strip **4** is pressure cured inside a round curing mold **16**, after being looped about body ply **2**. In an alternative embodiment, tread strip **4** is pressure cured on its own inside a flat curing mold **16**; and only later is the precured tread (PCT) strip **4** looped about body ply **2**, in the same way, for example, as when retreading tyres.

Tread strip **4** described has numerous advantages.

In particular, noise emissions, as tread strip **4** rolls along the road surface, are greatly reduced, as compared with an identical tread strip **4** with no pins **15**.

Having no appreciable effect on wet-pavement draining performance of grooves **9** or **10**, pins **15** in grooves **9** or **10** in no way affect wet-pavement performance of tread strip **4**. This is an important characteristic, in that it allows existing tread strips **4** to be modified by simply inserting pins **15**, with no alterations to the pattern of grooves **9** and **10**.

Pins **15** are relatively strong, have little contact with the road surface as the tyre rolls along (at least as long as tread strip **4** is not too badly worn), are therefore subjected to no mechanical stress, and so remain intact even after prolonged use.

Last but not least, pins **15** are cheap and easy to produce, by simply forming holes **24** in curing mold **16**; which means existing curing molds **16** can be modified easily, as opposed to providing new ones.

The invention claimed is:

1. A tread strip made of at least one rubber-based material, comprising:
   at least one longitudinal groove bounded by a bottom wall and by two lateral walls on opposite sides of the bottom wall; and
   a number of pins, each of which projects from at least one wall of the longitudinal groove, is a seamless outgrowth of the wall of the longitudinal groove, and is made seamlessly of the same rubber-based material as the tread strip;
   wherein the pins are distributed randomly along the longitudinal groove, so the pins as a whole do not form a regular structure, and
   wherein the pins cover 0.45% to 25% of the total surface area of each wall of the longitudinal groove.

2. The tread strip as claimed in claim **1**, wherein the longitudinal distances between consecutive pins are randomly distributed.

3. The tread strip as claimed in claim **2**, wherein the longitudinal distances between consecutive pins comprise a large number of different longitudinal distances with no multiple/submultiple relationship.

4. The tread strip as claimed in claim **1**, wherein the longitudinal distances between consecutive pins are assumed to be randomly distributed when the longitudinal distances have at least two occurrence frequencies in the set defined as follows:

$$\theta_0 = 2 \cdot D_{PIN}/D_{TYRE}$$

$$\theta_i = i \cdot \theta_0$$

$$n_i = \text{occurrence between } \theta_i \text{ and } \theta_{i+1}$$

$$A = \{n_i : n_i \epsilon [1, 2\pi/(\Theta_{i+1} \cdot K]; i=1, 2, \ldots, \alpha_{FP}/(2 \cdot \theta_0)\}$$

D_{PIN} diameter of a pin;
D_{TYRE} diameter of the tyre;
α_{FP} footprint angle;
K safety coefficient greater than one.

5. The tread strip as claimed in claim **1**, wherein, in each footprint of the tread strip the pins in the longitudinal groove are distributed so that, when viewed longitudinally, the pins as a whole cover at least 80% of the cross section of the longitudinal groove.

6. The tread strip as claimed in claim **1**, wherein the circular cross section of each pin has a diameter of 0.3 to 1.2 mm.

7. The tread strip as claimed in claim **1**, wherein the pins projecting from the bottom wall of the longitudinal groove are of a length ranging between 60% and 90% of the depth of the longitudinal groove.

8. The tread strip as claimed in claim **1**, wherein the pins in the longitudinal groove occupy a volume no greater than 10% of the total volume of the longitudinal groove.

9. The tread strip as claimed in claim **1**, wherein the pins form an angle of other than at the point of attachment to the wall of the longitudinal groove from which they project.

10. The tread strip as claimed in claim **1**, wherein the pins projecting from the lateral walls of the longitudinal groove all originate from an area ranging between the bottom wall and half the overall depth of the longitudinal groove.

11. The tread strip as claimed in claim **1**, wherein at least one pin is other than straight.

12. The tread strip as claimed in claim **1**, and comprising a number of longitudinal grooves, and a number of transverse grooves intersecting the longitudinal grooves; the pins being provided in both the longitudinal grooves and the transverse grooves.

13. The tread strip as claimed in claim **1**, wherein the two lateral walls of the longitudinal groove form two corresponding edges with a rolling surface; each edge being rounded with no sharp edges.

14. The tread strip as claimed in claim **13**, wherein each edge is rounded with a circular cross section.

15. The tread strip as claimed in claim **13**, wherein each edge is rounded with a radius ranging between 40% and 85% of the length of the pins.

16. The tread strip as claimed in claim **13**, wherein each edge is rounded with a radius of 3 to 5 mm.

17. The tread strip as claimed in claim **1**, and made of a first rubber-based material that forms most of the tread strip; and a second rubber-based material, that is different from the first material, is located at the longitudinal groove, and forms at least one wall of the longitudinal groove, and the pins projecting from that wall.

18. A tyre comprising a toroidal body ply, which has two beads and supports the tread strip wound about the body ply and as claimed in claim **1**.

19. The tread strip as claimed in claim **1**, wherein, in each footprint of the tread strip, the pins in the longitudinal groove

are distributed so that, when viewed longitudinally, the pins as a whole cover 100% of the cross section of the longitudinal groove.

20. A tread strip made of at least one rubber-based material, and comprising:

at least one longitudinal groove bounded by a bottom wall and by two lateral walls on opposite sides of the bottom wall; and

a number of pins, each of which projects from at least one wall of the longitudinal groove, is a seamless outgrowth of the wall of the longitudinal groove, and is made seamlessly of the same rubber-based material as the tread strip;

wherein the pins are distributed randomly along the longitudinal groove, so the pins as a whole do not form a regular structure, and

wherein the longitudinal distances between consecutive pins are assumed to be randomly distributed when the longitudinal distances have at least two occurrence frequencies in the set defined as follows:

$$\theta_0 = 2 \cdot D_{PIN}/D_{TYRE}$$

$$\theta_i = i \cdot \theta_0$$

$$n_i = \text{occurrence between } \theta_i \text{ and } \theta_{i+1}$$

$$A = \{n_i : n_i \epsilon [1, 2\pi/(\Theta_{i+1} \cdot K]; i=1, 2, \ldots, \alpha_{FP}/(2 \cdot \theta_0)\}$$

D_{PIN} diameter of a pin;
D_{TYRE} diameter of the tyre;
α_{FP} footprint angle;
K safety coefficient greater than one.

21. A tread strip made of at least one rubber-based material, and comprising:

at least one longitudinal groove bounded by a bottom wall and by two lateral walls on opposite sides of the bottom wall; and

a number of pins, each of which projects from at least one wall of the longitudinal groove, is a seamless outgrowth of the wall of the longitudinal groove, and is made seamlessly of the same rubber-based material as the tread strip;

wherein the pins are distributed randomly along the longitudinal groove, so the pins as a whole do not form a regular structure, and

wherein the pins form an angle of other than 90° at the point of attachment to the wall of the longitudinal groove from which they project.

22. A tread strip made of at least one rubber-based material, and comprising:

at least one longitudinal groove bounded by a bottom wall and by two lateral walls on opposite sides of the bottom wall; and

a number of pins, each of which projects from at least one wall of the longitudinal groove, is a seamless outgrowth of the wall of the longitudinal groove, and is made seamlessly of the same rubber-based material as the tread strip;

wherein the pins are distributed randomly along the longitudinal groove, so the pins as a whole do not form a regular structure, and

wherein the pins projecting from the lateral walls of the longitudinal groove all originate from an area ranging between the bottom wall and half the overall depth of the longitudinal groove.

23. A tread strip made of at least one rubber-based material, and comprising:

at least one longitudinal groove bounded by a bottom wall and by two lateral walls on opposite sides of the bottom wall; and

a number of pins, each of which projects from at least one wall of the longitudinal groove, is a seamless outgrowth of the wall of the longitudinal groove, and is made seamlessly of the same rubber-based material as the tread strip;

wherein the pins are distributed randomly along the longitudinal groove, so the pins as a whole do not form a regular structure, and

wherein the two lateral walls of the longitudinal groove form two corresponding edges with a rolling surface; each edge being rounded with no sharp edges.

24. The tread strip as claimed in claim 23, wherein each edge is rounded with a circular cross section.

25. The tread strip as claimed in claim 23, wherein each edge is rounded with a radius ranging between 40% and 85% of the length of the pins.

26. The tread strip as claimed in claim 23, wherein each edge is rounded with a radius of 3 to 5 mm.

* * * * *